TMDLS FOR TURBIDITY FOR BAYOU DEVIEW AND CACHE RIVER, AR

FINAL
January 6, 2006

TMDLS FOR TURBIDITY FOR
BAYOU DEVIEW AND CACHE RIVER, AR

Prepared for

EPA Region VI
Water Quality Protection Division
Permits, Oversight, and TMDL Team
Dallas, TX 75202

Contract No. 68-C-02-108
Task Order #89

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EXECUTIVE SUMMARY

Section 303(d) of the Federal Clean Water Act requires states to identify waterbodies that are not meeting water quality standards and to develop total maximum daily pollutant loads for those waterbodies. A total maximum daily load (TMDL) is the amount of a pollutant that a waterbody can assimilate without exceeding the established water quality standards for that pollutant. Through a TMDL, pollutant loads can be allocated to point sources and nonpoint sources discharging to the waterbody.

The study area for this project is the Bayou DeView and Cache River watersheds in northeastern Arkansas. The study area is part of the Arkansas Department of Environmental Quality (ADEQ) Planning Segment 4B and is located within the Delta ecoregion. Land use in the study area is about 77% cropland and 17% forest.

Five reaches on Bayou DeView and 11 reaches of the Cache River are included on the draft 2004 Arkansas 303(d) list as not supporting the aquatic life use due to exceedances of numeric criteria for turbidity. In Arkansas Regulation No. 2, Bayou DeView and the Cache River are specified as “channel-altered” streams. The applicable numeric criteria for turbidity for these streams are 75 NTU (“primary” value) and 250 NTU (“storm-flow” value).

ADEQ historical water quality data were available for six locations in the study area. These data were analyzed for long term trends, seasonal patterns, relationships between concentration and stream flow, and relationships between turbidity and total suspended solids (TSS). The seasonal analysis showed that the highest values of turbidity and TSS tended to occur during the winter and spring, although some exceedence of the turbidity standards occurred throughout the year. There were no noticeable relationships between concentration and flow. Most of the data showed some correlation between turbidity and TSS, with higher turbidity levels tending to correspond with higher TSS values.

These TMDLs were expressed using TSS as a surrogate for turbidity because turbidity cannot be expressed as a mass load. Two regressions between TSS and turbidity were developed for each ADEQ water quality monitoring station, one for base flow conditions and one for storm-flow conditions. The base flow regressions were used to develop target TSS concentrations corresponding to the primary turbidity criterion of 75 NTU. The storm-flow regressions were used to develop target TSS concentrations corresponding to the storm-flow turbidity criterion of 250 NTU.

The TMDLs in this report were developed using the load duration curve methodology. This method illustrates allowable loading at a wide range of stream flow conditions. The steps for applying this methodology for the TMDLs in this report were:

1. Developing a flow duration curve,
2. Converting the flow duration curve to a load duration curve,
3. Plotting observed loads with the load duration curve,
4. Calculating the TMDL components, and
5. Calculating percent reductions.

The load duration curve was developed using multiple target TSS concentrations because Arkansas has different turbidity criteria for different flow conditions. Each target TSS concentration corresponding to the primary turbidity criterion was applied between the 100% exceedence of stream flow and the 60% exceedence of stream flow. Each target TSS concentration corresponding to the storm-flow turbidity criterion was applied between the 60% exceedence of stream flow and the 0% exceedence of stream flow.

The wasteload allocations (WLAs) for point source contributions were set to zero because TSS in these TMDLs was considered to represent inorganic suspended solids (i.e., soil and sediment particles from erosion or sediment resuspension). The suspended solids discharged by point sources in the study area are assumed to consist primarily of organic solids rather than inorganic solids. Discharges of organic suspended solids from point sources are already addressed by ADEQ through their permitting of point sources to maintain water quality standards for dissolved oxygen. The WLAs to support these TMDLs will not require any changes to the permits concerning inorganic suspended solids. Therefore, future growth for these permits or new permits would not be restricted by these turbidity TMDLs.

An implicit margin of safety (MOS) was incorporated through the use of conservative assumptions. The primary conservative assumption was calculating the TMDLs assuming that TSS is a conservative parameter and does not settle out of the water column.

The percent reductions shown in Table ES.1 were calculated using methodology that is slightly different than the assessment criteria used by ADEQ to develop the 2004 draft 303(d) list. These differences caused the assessment for the 2004 draft 303(d) list to indicate 16 stream reaches in the Bayou DeView and Cache River watersheds are impaired and the TMDL analysis to indicate that two of those reaches (08020302-007 and -009) are not impaired. The 2004 draft 303(d) list is still being reviewed by EPA and has not been finalized yet.

Table ES.1. Summary of turbidity TMDLs.

Reach ID	Stream Name	Flow Category	Loads (tons/day of TSS)				Percent Reduction Needed
			WLA	LA	MOS	TMDL	
08020302-004	Bayou DeView	Base flow	0	15.2	0	15.2	35%
		Storm-flow	0	181	0	181	0%
08020302-005	Bayou DeView	Base flow	0	12.2	0	12.2	35%
		Storm-flow	0	146	0	146	0%
08020302-006	Bayou DeView	Base flow	0	10.8	0	10.8	35%
		Storm-flow	0	129	0	129	0%
08020302-007	Bayou DeView	Base flow	0	3.04	0	3.04	0%
		Storm-flow	0	112	0	112	0%
08020302-009	Bayou DeView	Base flow	0	1.88	0	1.88	0%
		Storm-flow	0	69.2	0	69.2	0%
08020302-016	Cache River	Base flow	0	21.3	0	21.3	35%
		Storm-flow	0	225	0	225	0%
08020302-017	Cache River	Base flow	0	19.4	0	19.4	35%
		Storm-flow	0	205	0	205	0%
08020302-018	Cache River	Base flow	0	19.1	0	19.1	35%
		Storm-flow	0	202	0	202	0%
08020302-019	Cache River	Base flow	0	16.7	0	16.7	35%
		Storm-flow	0	176.9	0	176.9	0%
08020302-020	Cache River	Base flow	0	19.3	0	19.3	0%
		Storm-flow	0	347	0	347	17%
08020302-021	Cache River	Base flow	0	17.3	0	17.3	0%
		Storm-flow	0	311	0	311	17%
08020302-027	Cache River	Base flow	0	10.5	0	10.5	13%
		Storm-flow	0	304	0	304	0%
08020302-028	Cache River	Base flow	0	9.22	0	9.22	13%
		Storm-flow	0	267	0	267	0%
08020302-029	Cache River	Base flow	0	8.22	0	8.22	13%
		Storm-flow	0	238	0	238	0%
08020302-031	Cache River	Base flow	0	7.47	0	7.47	13%
		Storm-flow	0	216	0	216	0%
08020302-032	Cache River	Base flow	0	6.43	0	6.43	13%
		Storm-flow	0	186	0	186	0%

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1.0 INTRODUCTION

This report presents total maximum daily loads (TMDLs) for siltation/turbidity for 5 reaches of Bayou DeView and 11 reaches of the Cache River in northeastern Arkansas. These stream reaches were included on the Arkansas Department of Environmental Quality (ADEQ) draft 2004 Arkansas 303(d) list (ADEQ 2005) as not supporting their designated use of aquatic life. The sources of contamination and causes of impairment from the 303(d) listing are shown below in Table 1.1. The TMDLs in this report were developed in accordance with Section 303(d) of the Federal Clean Water Act and the Environmental Protection Agency's (EPA) regulations in 40 CFR 130.7.

The purpose of a TMDL is to determine the pollutant loading that a waterbody can assimilate without exceeding the water quality standards for that pollutant and to establish the load reduction that is necessary to meet the standard in a waterbody. The TMDL is the sum of the wasteload allocation (WLA), the load allocation (LA), and a margin of safety (MOS). The WLA is the load allocated to point sources of the pollutant of concern. The LA is the load allocated to nonpoint sources, including natural background. The MOS is a percentage of the TMDL that takes into account any lack of knowledge concerning the relationship between pollutant loadings and water quality.

Table 1.1. 303(d) listing for stream reaches in this task order.

Reach No.	Stream Name	Sources	Causes	Category	Priority
08020302-004	Bayou DeView	Agriculture	Siltation/Turbidity	5b	Low
08020302-005	Bayou DeView	Agriculture	Siltation/Turbidity	5b	Low
08020302-006	Bayou DeView	Agriculture	Siltation/Turbidity	5b	Low
08020302-007	Bayou DeView	Agriculture	Siltation/Turbidity	5b	Low
08020302-009	Bayou DeView	Agriculture	Siltation/Turbidity	5b	Low
08020302-016	Cache River	Agriculture	Siltation/Turbidity	5b	Low
08020302-017	Cache River	Agriculture	Siltation/Turbidity	5b	Low
08020302-018	Cache River	Agriculture	Siltation/Turbidity	5b	Low
08020302-019	Cache River	Agriculture	Siltation/Turbidity	5b	Low
08020302-020	Cache River	Agriculture	Siltation/Turbidity	5b	Low
08020302-021	Cache River	Agriculture	Siltation/Turbidity	5b	Low
08020302-027	Cache River	Agriculture	Siltation/Turbidity	5b	Low
08020302-028	Cache River	Agriculture	Siltation/Turbidity	5b	Low
08020302-029	Cache River	Agriculture	Siltation/Turbidity	5b	Low
08020302-031	Cache River	Agriculture	Siltation/Turbidity	5b	Low
08020302-032	Cache River	Agriculture	Siltation/Turbidity	5b	Low

2.0 BACKGROUND INFORMATION

2.1 General Information

The study area for this project is the Bayou DeView and Cache River watersheds in northeastern Arkansas (see Figure A.1 in Appendix A). The Bayou DeView and Cache River watersheds are in the Delta ecoregion and in ADEQ Planning Segment 4B. Bayou DeView and the Cache River are also in United States Geological Survey (USGS) Hydrologic Unit 08020302. The study area covers 1,785 square miles and includes parts of Clay, Greene, Lawrence, Craighead, Jackson, Poinsett, Woodruff, Cross, Prairie, and Monroe Counties.

2.2 Soils and Topography

The soils and topography information was obtained from soil surveys for Clay, Greene, Lawrence, Craighead, Jackson, Cross, and Monroe Counties (United States Department of Agriculture (USDA) 1969, 1978a, 1978b, 1979, 1974, 1968, 1978c). Most of the study area is characterized by loamy and clayey soils and flat topography. The exception to this is Crowley's Ridge, which is a hilly area with more silty soils along the eastern edge of the Cache River watershed north of Jonesboro. The topography of Crowley's Ridge forms a sharp contrast to the remainder of the study area.

2.3 Land Use

Land use data for the study area were obtained from the GEOSTOR database, which is maintained by the Center for Advanced Spatial Technology (CAST) at the University of Arkansas in Fayetteville. These data were based on satellite imagery from 1999. The spatial distribution of these land use is shown on Figure A.2 (located in Appendix A) and land use percentages are shown in Table 2.1. These data indicate that the study area is about 77% cropland and 17% forest. Most of the forest occurs along Crowley's Ridge and in the floodplains along some of the lower reaches of Bayou DeView and the Cache River.

Table 2.1. Land use percentages for the study area.

Land use	Percentage of study area
Urban	0.5%
Water	1.3%
Forest (all types)	17.0%
Soybeans	48.5%
Rice	24.0%
Cotton	0.6%
Corn	4.4%
Pasture	3.7%
Total	100.0%

2.4 Description of Hydrology

Average precipitation for the study area is about 47-50 inches per year (USGS 1985). There are two USGS flow gages in the study area; information for these gages is summarized in Table 2.2. Flow data for each gage were used to characterize different portions of the study area.

Table 2.2. Information for USGS stream flow gaging stations (USGS 2005).

Gage name:	Cache River near Cotton Plant	Cache River at Egypt
Gage number:	07077555	07077380
Descriptive location:	Bridge on county road, 4.2 miles northwest of Cotton Plant	Bridge at State Highway 91, 1.0 mile southeast of Egypt
Period of record:	May 1987 – September 2004	October 1964 – September 2004
Drainage area:	1,172 square miles	701 square miles
Mean daily flow:	1,376 cfs	868 cfs
Median daily flow:	800 cfs	328 cfs

2.5 Water Quality Standards

Water quality standards for Arkansas waterbodies are listed by ecoregion in Regulation No. 2 (Arkansas Pollution Control and Ecology Commission (APCEC) 2004a). Designated uses for Bayou DeView and the Cache River include primary and secondary contact recreation; public, industrial, and agricultural water supply; and perennial Delta fishery (where the drainage area is 10 square miles or more). In addition, a portion of the Cache River above Cache Bayou is designated as an Extraordinary Resource Water (ERW). The portion of the Cache River to which the ERW designation applies includes nearly all of reach 08020302-018. This designation does not affect the narrative or numeric turbidity criteria for this reach.

Section 2.503 of Regulation No. 2 provides both a narrative criterion and numeric criteria that apply to siltation/turbidity. The general narrative criterion is: “There shall be no distinctly visible increase in turbidity of receiving waters attributable to municipal, industrial, agricultural, other waste discharges or instream activities.” For the Delta ecoregion, there are different numeric criteria for turbidity for “least-altered” and “channel-altered” streams. Appendix A of Regulation No. 2 specifies Bayou DeView and Cache River as channel-altered streams. The numeric turbidity criteria for channel-altered streams in the Delta ecoregion are 75 NTU (“primary” value) and 250 NTU (“storm-flow” value). The regulation also states that “the non-point source runoff shall not result in the exceedance of the in stream storm-flow values in more than 20% of the ADEQ ambient monitoring network samples taken in not less than 24 monthly samples.”

As specified in EPA's regulations at 40 CFR 130.7(b)(2), applicable water quality standards include antidegradation requirements. Arkansas' antidegradation policy is listed in Sections 2.201 through 2.204 of Regulation No. 2. These sections impose the following requirements:

- Existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.
- Water quality that exceeds standards shall be maintained and protected unless allowing lower water quality is necessary to accommodate important economic or social development, although water quality must still be adequate to fully protect existing uses.
- For outstanding state or national resource waters, those uses and water quality for which the outstanding waterbody was designated shall be protected.
- For potential water quality impairments associated with a thermal discharge, the antidegradation policy and implementing method shall be consistent with Section 316 of the Clean Water Act.

2.6 Nonpoint Sources

In the draft 2004 303(d) list, the source of turbidity for Bayou DeView and Cache River is listed as agriculture. As shown in Table 2.1, over 77% of the study area is cropland, which typically has greater soil erosion than other land uses such as forest or pasture.

2.7 Point Sources

Information for point source discharges in the study area was obtained by searching the Permit Compliance System on the EPA web site (PCS 2005). The search yielded 37 facilities with point source discharges. Search results, including flow rate and permit limits for total suspended solids (TSS) and turbidity, are included in Tables 2.3a and 2.3b. Locations of the permitted facilities are shown on Figure A.3 in Appendix A.

Table 2.3a. Inventory of point source discharges in Bayou DeView watershed.

NPDES Permit No.	Facility Name	Receiving Water	Flow Rate (MGD)	Monthly Average TSS Limits (mg/L)
AR0020354	City of Weiner	Trib, Bayou DeView	0.60	20
AR0022446	City of Fisher	Trib, Bayou DeView	0.08	20
AR0037834	Riceland - Waldenburg	Ditch, Bayou DeView	0.005	20
AR0037907	Jonesboro – West	Trib, Big Creek, B. DeView	3.00	20
AR0041629	Westside Consol	Trib, Big Creek, B. DeView	0.03	15
AR0042188	Northern Mobile	Trib, Big Creek, B. DeView	0.01	15
AR0044211	Holy Angels Conv	Lost Crk, Big Crk, B. DeView	0.01	30
AR0046981	Hedger Aggregate	Mud Cr., Big Cr., B. DeView	0.71	20
AR0048402	LMJ Trailer Park	Trib, Big Creek, B. DeView	0.02	20

Table 2.3b. Inventory of point source discharges in Cache River watershed.

NPDES Permit No.	Facility Name	Receiving Water	Flow Rate (MGD)	Monthly Average TSS Limits (mg/L)
AR0020699	City of Bono	Trib/Whaley Slough, Cache R	0.25	20
AR0034614	City of Grubbs	Cache River	0.09	90
AR0035947	Crowley's Ridge State Prk	Ditch, Big Ditch, Cache R.	0.04	15
AR0042552	Tri-County Sand & Gravel	Dort Creek, Cache River	0.27	20
AR0042781	McDougal WWTF	Ditch, Cache River	0.10	0 / 90
AR0043290	Knobel WWTF	Trib, Cache River	0.05	15
AR0043443	City of Sedgwick	W Cache R. Ditch, Cache R.	0.05	0 / 90
AR0043486	Tri-City Utilities, Inc.	Trib, Beaver Dam Ditch	0.05	15 / 20
AR0043524	Egypt Sewer System	W Cache R. Ditch, Cache R.	0.03	90
AR0044954	City of McCrory	Cache River	0.39	30
AR0045284	City of Cash	Trib, Cache River	0.02	15
AR0045489	City of Pollard	Pollard Creek, Ditch #2, #1	0.03	20
AR0046604	City of Amagon	Trib, Cache River	0.02	20
AR0048909	Town of Lafe	Big Creek, Cache River	0.05	20
AR0049603	City of Beedeville	Cache River	0.02	90
ARG160019	Jackson County Landfill	Ditch, Brewer Lake, Cache R.	0.005	--
ARG160033	Jackson County Landfill	Trib, Brewer Creek, Cache R.	0.03	--

3.0 EXISTING WATER QUALITY FOR TURBIDITY AND TSS

3.1 General Description of Data

Turbidity and TSS data have been collected by ADEQ at six sites in the study area. The locations of these sampling sites are shown on Figure A.4 (located in Appendix A). TSS data are discussed here because TSS is needed as a surrogate parameter for expressing the siltation/turbidity TMDLs. These turbidity and TSS data were obtained from the ADEQ web site (ADEQ 2005) and are summarized in Table 3.1. The individual data are listed in Tables B.1-B.6 and shown graphically as time series plots on Figures B.1-B.12 (located in Appendix B). The data for the sampling stations starting with “BDV” or “CHR” are stored in the ADEQ database under slightly different station names than those used in this report (e.g. “UWBDV02” is used in the ADEQ database instead of “BDV0002”). The station names used in this report are the names most commonly used for these stations.

Table 3.1. Summary of ADEQ data for turbidity and TSS.

Station	Description	Parameter	Count	Min.	Median	Average	Max.
BDV0002	Bayou DeView at Hwy. 64, 4 mi. E. of McCrory, AR	Turbidity	20	4.0	83.2	101.3	458
		TSS	20	11	48.5	56.4	170
WHI0026	Bayou DeView west of Gibson, AR	Turbidity	164	1.1	52.8	81.3	760
		TSS	154	1.0	29.1	71.5	1358
WHI0032	Cache River near Brasfield, AR	Turbidity	20	23.0	65.5	81.8	198
		TSS	20	10.3	24.2	25.2	50
CHR0002	Cache River at Hwy. 64 at Patterson, AR	Turbidity	20	18.0	91.0	125.5	410
		TSS	20	7.3	33.5	36.3	89
CHR0003	Cache River at Hwy. 18 near Grubbs, AR	Turbidity	20	2.8	75.6	138.3	410
		TSS	20	35.3	65.2	102.6	322
CHR0004	Cache River at Hwy, 412, 6 1/2 mi. E. of Walnut Ridge, AR	Turbidity	20	17.0	80.5	142.0	469
		TSS	20	5.3	73.3	100.2	480

Tables B.1-B.6 include comparisons between the observed turbidity data and the numeric water quality criteria. These comparisons required the observed data to be separated into base flow data (to be compared with the “primary” criterion) and storm-flow data (to be compared with the “storm-flow” criterion). It was assumed here that the lowest 40% of stream flow values represent flow conditions without significant influence from storm runoff and that stream flow values above the 40th percentile would have some influence from storm runoff. The turbidity data were considered to be base flow data when the flow on the sampling day was 554 cfs or less at the USGS gage on the Cache River near Cotton Plant or 189 cfs or less at the USGS gage on the Cache River near Egypt. These flows (554 cfs and 189 cfs) are the 40th percentile flows, or the flows that were exceeded 60% of the time. The turbidity data were considered to be storm-flow data when the flow on the sampling day was more than 554 cfs at the USGS gage on the Cache River near Cotton Plant or more than 189 cfs at the USGS gage on the Cache River near Egypt. Table 3.2 summarizes the percentages of the observed data for each station that exceeded the primary and storm-flow criteria over the period of record.

Table 3.2. Percentage of observed data exceeding primary and storm-flow criteria.

Sampling Station	Period of Record	Percent Exceeding Primary Criterion	Percent Exceeding Storm-flow Criterion
BDV0002	1994-2003	67%	0%
WHI0026	1990-2005	13%	8%
WHI0032	1994-2003	22%	0%
CHR0002	1994-2003	50%	21%
CHR0003	1994-2003	30%	30%
CHR0004	1994-2003	40%	40%

3.2 Seasonal Patterns

Seasonal plots of turbidity and TSS are shown on Figures C.1-C.12 (located in Appendix C). Most of these plots showed that the highest values of turbidity and TSS occurred during the winter and spring, which is usually the period of the year when many cropland fields are bare and stream flows are higher. At station WHI0026, exceedances of water quality criteria for turbidity occurred throughout the year. Exceedances of turbidity criteria throughout the year might have been detected at other sampling stations if more data had been collected.

3.3 Relationships Between Concentration and Flow

Plots of turbidity and TSS versus stream flow were also developed to examine any correlation between these two parameters (Figures D.1-D.12, located in Appendix D). These plots showed no noticeable relationship between concentration and flow.

3.4 Relationships Between TSS and Turbidity

Plots and regression analyses were used to examine relationships between TSS and turbidity. The regressions were performed using the natural logarithms of the data (rather than the raw data values) because most data such as turbidity and TSS fit a lognormal distribution better than a normal distribution.

Separate plots and regression analyses were developed for base flow conditions and storm-flow conditions to be consistent with the numeric criteria for turbidity. The plots and linear regressions for base flow conditions (Figures E.1, E.3, E.5, E.7, E.9, and E.11) use only the base flow data. The plots and linear regressions for storm-flow conditions (Figures E.2, E.4, E.6, E.8, E.10, and E.12) use all of the data regardless of flow on the sampling day. The data collected under base flow conditions were included in the storm-flow regression in order to maximize the accuracy of the lower end of the regression lines that correspond to turbidity values near the numeric criteria.

Noticeable correlations are evident in most of these plots, with higher turbidity levels tending to correspond with higher TSS concentrations. The results of the linear regression analyses are summarized in Table 3.2.

The strength of the linear relationship is measured by the coefficient of determination (R^2) calculated during the regression analysis (Zar 1996). The R^2 value is the percentage of the total variation in ln TSS that is explained or accounted for by the fitted regression (ln turbidity). For example, in the storm-flow regression for BDV0002 in Table 3.2, 66% of the variation in TSS is accounted for by turbidity and the remaining 34% of variation in TSS is unexplained. The unexplained portion is attributed to factors other than the measured value of turbidity.

Table 3.2. Results of regressions between TSS and turbidity.

Sampling Station	Category	Regression Equation	Number of Data	R^2	Significance Level (P value)
BDV0002	Base flow	ln TSS = 0.697 * ln Turbidity + 1.06	5	0.76	0.055
	Storm-flow	ln TSS = 0.546 * ln Turbidity + 1.53	19	0.66	2.3×10^{-5}
WHI0026	Base flow	ln TSS = 0.674 * ln Turbidity + 0.704	59	0.47	2.3×10^{-9}
	Storm-flow	ln TSS = 0.757 * ln Turbidity + 0.616	153	0.52	1.4×10^{-25}
WHI0032	Base flow	ln TSS = 0.292 * ln Turbidity + 2.07	6	0.43	0.157
	Storm-flow	ln TSS = 0.024 * ln Turbidity + 3.07	19	0.002	0.872
CHR0002	Base flow	ln TSS = 0.891 * ln Turbidity - 0.646	5	0.53	0.165
	Storm-flow	ln TSS = 0.452 * ln Turbidity + 1.33	19	0.30	0.014
CHR0003	Base flow	ln TSS = 0.351 * ln Turbidity + 2.80	9	0.57	0.018
	Storm-flow	ln TSS = 0.350 * ln Turbidity + 2.86	19	0.43	0.002
CHR0004	Base flow	ln TSS = 1.024 * ln Turbidity - 0.314	9	0.60	0.015
	Storm-flow	ln TSS = 0.796 * ln Turbidity + 0.662	19	0.62	6.3×10^{-5}

Note: Regression results in shaded rows were not used to develop TMDLs.

Most of these regressions show a majority of the measurement of the turbidity (NTU) is explained by the measured concentration of TSS. The perfect explanation of the measurement of turbidity to the measurement of TSS would require collecting and analyzing a large amount of data. A number of the items effecting this perfect explanation of the relationship would need to be known. A partial list of the items effecting the relationship follows:

- Velocity of the water at the time of sampling;
- Carbonaceous biochemical oxygen demand (CBOD) concentration;
- Ammonia concentration;
- Nitrate concentration;
- Phosphorus concentration;
- Algal mass in the water column;
- Bacteria mass in the water;
- Measured color of the water;
- Mass of the organic component of the TSS;
- Mass of the material passing through the filter during the TSS analysis;
- Grain size distribution of the inorganic portion of the TSS;
- Specific gravity of the different sizes of inorganic solids particles;
- Hydrograph for the stream;
- Position on the hydrograph (i.e., rising limb, falling limb) at the time of sampling;
- Number of overlapping rainfall events represented by this sample day;
- Magnitude of each of the rainfall events represented by this sample day; and

- Lags of the overlapping rainfall events represented by this sample day.

The collection of the above data would not change the fact that inorganic particles represented in the TSS measurements is the major contributor to the turbidity reading and is the major constituent reduced when sediment BMPs are applied to nonpoint sources. The BMPs used on nonpoint sources for sediment also reduce the load of many of the unexplained contributors in the regression. The effort to have a perfect explanation of turbidity may not result in a better selection of BMPs. The regressions presented above between TSS and turbidity are adequate for the preparation of this TMDL. A stakeholder group of knowledgeable persons from the watershed may need additional information to set a plan of action for this TMDL.

The correlations between turbidity and TSS for Bayou DeView and Cache River ranged from good to very poor. Except for WHI0032, the R^2 values for these regressions were within the range of R^2 values for turbidity and TSS from other approved TMDLs in Arkansas (FTN 2001, FTN 2003, FTN 2005).

The statistical significance of the regression was evaluated by computing the “P value” for the slope of the regression line. The P value is essentially the probability that the slope of the regression line is really zero. Thus, a low P value indicates that a non-zero slope calculated from the regression analysis is statistically significant. For these regressions, the P values ranged from very good (1.4×10^{-25}) to very poor (0.872).

Because some of the regressions had poor correlation and/or poor statistical significance, not all of the regressions were used in development of these TMDLs (see Section 4.2).

4.0 TMDL DEVELOPMENT

4.1 Seasonality and Critical Conditions

EPA's regulations at 40 CFR 130.7 require the determination of TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. Also, both Section 303(d) of the Clean Water Act and regulations at 40 CFR 130.7 require TMDLs to consider seasonal variations for meeting water quality standards. The historical data analysis in Section 3.0 showed that some exceedances of turbidity criteria occurred throughout the year and there was no noticeable correlation between streamflow and turbidity or TSS. Therefore, there is not a critical season or a single critical flow for these TMDLs. The methodology used to develop these TMDLs (load duration curve) addresses allowable loading for a wide range of flow conditions.

4.2 Water Quality Targets

Turbidity is an expression of the optical properties in a water sample that cause light to be scattered or absorbed and may be caused by suspended matter, such as clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, and plankton and other microscopic organisms (Standard Methods 1999). Turbidity cannot be expressed as a load as preferred for TMDLs. To achieve a load based value, turbidity is often correlated with a surrogate parameter such as TSS that may be expressed as a load. In general, activities that generate varying amounts of suspended sediment will proportionally change or affect turbidity (EPA 1991). Research by Relyea et. al. (2000) states, "increased turbidity by sediments can reduce stream primary production by reducing photosynthesis, physically abrading algae and other plants, and preventing attachment of autotrophs to substrate surfaces".

For the turbidity TMDLs in this report, target TSS concentrations (i.e., numeric endpoints for the TMDLs) were developed using some of the relationships between turbidity and TSS presented in Table 3.2. Some of the regression results in Table 3.2 were not used because the statistical significance (and in some cases the correlation, too) was poor. The four regression equations that were not used were the base flow regression for BDV0002, the base flow regression for WHI0032, the storm-flow regression for WHI0032, and the base flow regression for CHR0002.

Two target TSS concentrations were developed for each water quality monitoring station, except WHI0032. A base flow target was developed using the base flow regression and the primary turbidity criterion, and a storm-flow target was developed using the storm-flow regression and the storm-flow turbidity criterion. The exceptions to this were for BDV0002 and CHR0002, where the base flow targets were estimated using the storm-flow regression and the primary turbidity standard. For impaired reaches in the study area that do not have water quality monitoring stations, target TSS concentrations from the nearest water quality monitoring station were assigned to those reaches. The target TSS concentrations are shown in Table 4.1. The discussion in Section 3.1 associating the primary turbidity criterion with the base flow portion of the duration curve is the basis for using the descriptor "base flow" in this document for the conditions when the primary turbidity criterion should apply.

Table 4.1. TSS targets for Bayou DeView and Cache River TMDLs.

Water Quality Station	Regression	Turbidity Criterion	Target TSS	Reaches to Which Targets Were Applied
BDV0002	Base flow	75 NTU	49 mg/L	08020302-004, -005, -006
	Storm-flow	250 NTU	94 mg/L	
WHI0026	Base flow	75 NTU	37 mg/L	08020302-007, -009
	Storm-flow	250 NTU	121 mg/L	
CHR0002	Base flow	75 NTU	27 mg/L	08020302-016, -017, -018, -019
	Storm-flow	250 NTU	46 mg/L	
CHR0003	Base flow	75 NTU	75 mg/L	08020302-020, -021
	Storm-flow	250 NTU	121 mg/L	
CHR0004	Base flow	75 NTU	61 mg/L	08020302-027, -028, -029, -031, -032
	Storm-flow	250 NTU	157 mg/L	

4.3 Methodology for TMDL Calculations

The methodology used for the TMDLs in this report is the load duration curve. Because loading capacity varies as a function of the flow present in the stream, these TMDLs represent a continuum of desired loads over all flow conditions, rather than fixed at a single value. The basic elements of this procedure are documented on the Kansas Department of Health and

Environment web site (KDHE 2005). This method was used to illustrate allowable loading at a wide range of flows. The steps for how this methodology was applied for the TMDLs in this report can be summarized as follows:

1. Develop a flow duration curve (Section 4.4);
2. Convert the flow duration curve to load duration curves (Section 4.5);
3. Plot observed loads with load duration curves (Section 4.6);
4. Calculate TMDL, MOS, WLA, and LA (Sections 4.7-4.9); and
5. Calculate percent reductions (Section 4.10).

4.4 Flow Duration Curve

A flow per unit area duration curve was developed for the study area (see Table F.1 in Appendix F for details). Daily streamflow measurements from Cache River near Cotton Plant (USGS Gage No. 07077555) and Cache River at Egypt (USGS Gage No. 07077380) were sorted in increasing order and the percent exceedance of each flow was calculated. Each flow was then divided by the drainage area of the gage to get a flow per square mile. The flow per unit area duration curves are shown on Figures F.1 and F.2 in Appendix F.

4.5 Load Duration Curves

Each flow per unit area from the flow duration curve was multiplied by the appropriate TSS target concentration to develop plots of allowable load versus flow exceedence (Load duration curves). The water quality standards for Arkansas (APCEC 2004a) do not specify a range of flows or flow exceedances for which each of the turbidity criteria (primary and storm-flow) is applicable. As discussed in Section 3.1, it was assumed here that the lowest 40% of stream flow values represent flow conditions without significant influence from storm runoff and that stream flow values above the 40th percentile would have some influence from storm runoff. Therefore, each TSS target corresponding to the primary turbidity criterion was applied to the lowest 40% of flows (from 100% exceedence of stream flow to 60% exceedence of stream flow) and each TSS target corresponding to the storm-flow turbidity criterion was applied from 60% exceedence of stream flow to 0% exceedence of stream flow. The load duration curves for storm-flow conditions and base flow conditions are shown on Figures F.3-F.12 (in Appendix F).

4.6 Observed Loads

The observed loads per unit of drainage area for each of the water quality monitoring stations except WH10032 were calculated for each sampling day. Each observed load per unit of drainage area was calculated by simply multiplying the observed TSS concentration times the flow per unit of drainage area on the sampling day (with a conversion factor incorporated).

The load duration plots (Figures F.3-F.12) provide visual comparisons between observed and allowable loads under different flow conditions. Observed loads that are plotted above the load duration curve represent conditions where observed water quality concentrations exceed the target concentrations. Observed loads below the load duration curve represent conditions where observed water quality concentrations were less than target concentrations (i.e., not exceeding water quality criteria).

4.7 TMDL and MOS

The allowable loads per unit area for storm-flow conditions were calculated as the appropriate TSS target for storm-flow conditions (see Table 4.1) multiplied times the flow per unit area at the 30% flow exceedance. The 30% flow exceedance was used because it is considered to represent a typical flow value for storm-flow conditions (it is the midpoint along the flow duration curve between 0% and 60%). The allowable loads per unit area for base flow conditions were calculated as the appropriate TSS target for base flow conditions (see Table 4.1) multiplied times the flow per unit area at the 80% flow exceedance. The 80% flow exceedance was used because it is considered to represent a typical flow value for base flow conditions (it is the midpoint along the flow duration curve between 60% and 100%). The TMDLs were calculated as the allowable loads per unit area multiplied times the total drainage area at the downstream end of each reach. These calculations are shown at the bottom of Tables F.1-F.5.

Both Section 303(d) of the Clean Water Act and regulations at 40 CFR 130.7 require TMDLs to include a MOS to account for uncertainty in available data or in the actual effect that controls will have on the loading reductions and receiving water quality. The MOS may be expressed explicitly as unallocated assimilative capacity or implicitly through conservative assumptions used in establishing the TMDL. For these TMDLs, an implicit MOS was incorporated through the use of conservative assumptions. The primary conservative assumption was calculating the TMDLs assuming that TSS is a conservative parameter and does not settle out of the water column.

4.8 Point Source Loads

The WLAs for the point sources were set to zero because the surrogate being used for turbidity (TSS) is considered to represent inorganic suspended solids (i.e., soil and sediment particles from erosion or sediment resuspension). The suspended solids discharged by point sources in the Cache River and Bayou DeView watershed are assumed to consist primarily of organic solids rather than inorganic solids. Discharges of organic suspended solids from point sources are already addressed by ADEQ through their permitting of point sources to maintain water quality standards for dissolved oxygen. The WLAs to support these TMDLs will not require any changes to the permits concerning inorganic suspended solids. Therefore, future growth for these permits or new permits would not be restricted by these turbidity TMDLs.

4.9 Nonpoint Source Loads

The LAs for nonpoint sources, including natural background, result in being equal to the TMDLs because the WLAs were zero and the MOS was implicit.

4.10 Percent Reductions

In addition to calculating allowable loads, estimates were made for percent reductions of nonpoint source loads that are needed. For each station where the number of observed TSS loads exceeded the allowable loads was above an acceptable number (i.e., each observed TSS load above the allowable load curve in Figures F.3-F.12), a uniform percent reduction was applied to the observed loads in the plot until the number of TSS loads exceeding the allowable loads was less than or equal to an acceptable number. For storm-flow conditions, the acceptable number of exceedances was 20% of the number of storm-flow data. This percentage (20%) was based on the Arkansas water quality standards, which state that “the non-point source runoff shall not result in the exceedance of the in stream storm-flow values in more than 20% of the ADEQ ambient monitoring network samples taken in not less than 24 monthly samples.” (APCEC 2004a). For base flow conditions, the acceptable number of exceedances was 25% of the number of base flow data. This percentage (25%) was based on the ADEQ assessment criteria for turbidity (ADEQ 2002, ADEQ 2005a). For both storm-flow and base flow conditions, whenever the appropriate percentage multiplied by the number of observed values yielded a fractional number (e.g., 25% x 38 = 9.5), the allowable number of exceedances was rounded up to the next whole number (e.g., 9.5 rounded up to 10) in accordance with the ADEQ assessment criteria (ADEQ 2002, ADEQ 2005a). The calculations for percent reductions are shown in Tables F.6-F.15.

For the impaired reaches without water quality monitoring data, percent reductions were assumed to be the same as the nearest reach with observed water quality data (i.e., in a similar manner as done for the target TSS concentrations). These percent reductions and the results of the TMDL calculations are summarized in Table 4.2. These calculations indicated that 14 of the 16 impaired reaches required some reductions.

The percent reductions in Table 4.2 were calculated using methodology that is slightly different than the assessment criteria used by ADEQ to develop the 2004 303(d) list. The ADEQ assessment was performed using turbidity data that were categorized as either base flow or storm-flow values based on the month of the year in which the values were measured. The percent reductions in Table 4.2 were calculated using TSS data that were categorized as either base flow or storm-flow values based on streamflow data on each sampling day. These differences caused the assessment for the 2004 draft 303(d) list to indicate that 16 stream reaches in the Bayou DeView and Cache River watersheds are impaired and the TMDL analysis to indicate that two of those reaches (08020302-007 and -009) are not impaired. The 2004 draft 303(d) list is still being reviewed by EPA and has not been finalized yet.

Table 4.2. Summary of turbidity TMDLs.

Reach ID	Stream Name	Flow Category	Loads (tons/day of TSS)				Percent Reduction Needed
			WLA	LA	MOS	TMDL	
08020302-004	Bayou DeView	Base flow	0	15.2	0	15.2	35%
		Storm-flow	0	181	0	181	0%
08020302-005	Bayou DeView	Base flow	0	12.2	0	12.2	35%
		Storm-flow	0	146	0	146	0%
08020302-006	Bayou DeView	Base flow	0	10.8	0	10.8	35%
		Storm-flow	0	129	0	129	0%
08020302-007	Bayou DeView	Base flow	0	3.04	0	3.04	0%
		Storm-flow	0	112	0	112	0%
08020302-009	Bayou DeView	Base flow	0	1.88	0	1.88	0%
		Storm-flow	0	69.2	0	69.2	0%
08020302-016	Cache River	Base flow	0	21.3	0	21.3	35%
		Storm-flow	0	225	0	225	0%
08020302-017	Cache River	Base flow	0	19.4	0	19.4	35%
		Storm-flow	0	205	0	205	0%
08020302-018	Cache River	Base flow	0	19.1	0	19.1	35%
		Storm-flow	0	202	0	202	0%
08020302-019	Cache River	Base flow	0	16.7	0	16.7	35%
		Storm-flow	0	176.9	0	176.9	0%
08020302-020	Cache River	Base flow	0	19.3	0	19.3	0%
		Storm-flow	0	347	0	347	17%
08020302-021	Cache River	Base flow	0	17.3	0	17.3	0%
		Storm-flow	0	311	0	311	17%
08020302-027	Cache River	Base flow	0	10.5	0	10.5	13%
		Storm-flow	0	304	0	304	0%
08020302-028	Cache River	Base flow	0	9.22	0	9.22	13%
		Storm-flow	0	267	0	267	0%
08020302-029	Cache River	Base flow	0	8.22	0	8.22	13%
		Storm-flow	0	238	0	238	0%
08020302-031	Cache River	Base flow	0	7.47	0	7.47	13%
		Storm-flow	0	216	0	216	0%
08020302-032	Cache River	Base flow	0	6.43	0	6.43	13%
		Storm-flow	0	186	0	186	0%

4.11 Future Growth

As mentioned in Section 4.8, future growth of existing or new point source discharges would not be restricted by these TMDLs.

5.0 OTHER RELEVANT INFORMATION

In accordance with Section 106 of the federal Clean Water Act and under its own authority, ADEQ has established a comprehensive program for monitoring the quality of the State's surface waters. ADEQ collects surface water samples at various locations, utilizing appropriate sampling methods and procedures for ensuring the quality of the data collected. The objectives of the surface water monitoring program are to determine the quality of the state's surface waters, to develop a long-term data base for long term trend analysis, and to monitor the effectiveness of pollution controls. The data obtained through the surface water monitoring program is used to develop the state's biennial 305(b) report (*Water Quality Inventory*) and the 303(d) list of impaired waters, which are issued as a single document titled Arkansas Integrated Water Quality Monitoring and Assessment Report.

6.0 PUBLIC PARTICIPATION

When EPA establishes a TMDL, federal regulations require EPA to publicly notice and seek comment concerning the TMDL. Pursuant to a May 2000 consent decree, these TMDLs were prepared under contract to EPA. After development of the draft version of these TMDLs, EPA prepared a notice seeking comments, information, and data from the general public and affected public. No comments, data, or information were submitted during the public comment period. EPA has transmitted the final TMDLs to ADEQ for implementation and for incorporation into ADEQ's current water quality management plan.

7.0 REFERENCES

ADEQ. 2002. 2002 Arkansas Integrated Water Quality Monitoring and Assessment Report. Prepared pursuant to Section 305(b) of the Federal Water Pollution Control Act. Published by Arkansas Department of Environmental Quality.

ADEQ. 2005. Surface Water Quality Monitoring Data web site. Maintained by Technical Services Division, Arkansas Department of Environmental Quality. www.adeq.state.ar.us/techsvs/water_quality/monitors.asp

APCEC. 2004a. Regulation No. 2, As Amended. Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas. Published by Arkansas Department of Environmental Quality. April 23, 2004.

APCEC. 2004b. Regulation No. 6, Regulations for State Administration of the National Pollutant Discharge Elimination System (NPDES). Adopted by the Arkansas Pollution Control and Ecology Commission on March 26, 2004.

EPA. 1991. Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in Pacific Northwest. EPA 910/9-91/001. Region 10, U.S. Environmental Protection Agency, Seattle, WA.

FTN. 2001. TMDLs for Turbidity and Fecal Coliforms for L'Anguille River, AR. Report prepared for U.S. EPA Region 6 by FTN Associates. Final report dated October 2001.

FTN. 2003. TMDLs for Turbidity for Bayou Bartholomew, AR. Report prepared for U.S. EPA Region 6 by FTN Associates. Final report dated January 9, 2003.

FTN. 2005. TMDLs for Turbidity, Chloride, Sulfate, and TDS in the Boeuf River and Bayou Macon Basins, AR. Report prepared for U.S. EPA Region 6 by FTN Associates. Final report dated March 3, 2005.

KDHE. 2005. "Kansas TMDL Curve Methodology". Web site maintained by Kansas Department of Health and Environment. Dated December 1, 2005. www.kdheks.gov/tmdl/Data.htm

PCS. 2005. Permit Compliance System web site. Maintained by U.S. Environmental Protection Agency. www.epa.gov/enviro/html/pcs/adhoc.html

Relyea, C.D., C.W. Marshall, and R.J. Danehy. 2000. Stream insects as indicators of fine sediment. Stream Ecology Center, Idaho Sate University, Pocatello, ID. Presented at WEF 2000 Watershed Management Conference.

Standard Methods. 1999. Standard Methods for the Examination of Water and Wastewater. 20th Edition. Published by American Public Health Association, American Water Works Association, and Water Environment Federation.

USDA. 1979. Soil Survey for Craighead County, Arkansas. Published by Soil Conservation Service, U.S. Department of Agriculture in cooperation with Arkansas Agricultural Experiment Station. December 1979.

USDA. 1978a. Soil Survey for Clay County, Arkansas. Published by Soil Conservation Service, U.S. Department of Agriculture in cooperation with Arkansas Agricultural Experiment Station. July 1978.

USDA. 1978b. Soil Survey for Lawrence County, Arkansas. Published by Soil Conservation Service, U.S. Department of Agriculture in cooperation with Arkansas Agricultural Experiment Station. June 1978.

USDA. 1978c. Soil Survey for Monroe County, Arkansas. Published by Soil Conservation Service, U.S. Department of Agriculture in cooperation with Arkansas Agricultural Experiment Station. June 1978.

USDA. 1968. Soil Survey for Cross County, Arkansas. Published by Soil Conservation Service, U.S. Department of Agriculture in cooperation with Arkansas Agricultural Experiment Station. August 1978.

USDA. 1969. Soil Survey for Greene County, Arkansas. Published by Soil Conservation Service, U.S. Department of Agriculture in cooperation with Arkansas Agricultural Experiment Station. December 1979.

USDA. 1974. Soil Survey for Jackson County, Arkansas. Published by Soil Conservation Service, U.S. Department of Agriculture in cooperation with Arkansas Agricultural Experiment Station. December 1974.

USGS. 1985. Average Annual Precipitation and Runoff for Arkansas, 1951-1980. Water-Resources Investigations Report 84-4363. Prepared by D.A. Freiwald, U.S. Geological Survey, Little Rock, Arkansas.

USGS. 2005a. Water Resources Data Arkansas Water Year 2004. Water-Data Report AR-04-1. Prepared by T.H. Brossett, T.P. Schrader, and D.A. Evans, U.S. Geological Survey, Little Rock, AR. January 2005.

USGS. 2005b. Surface-Water Data for Arkansas web site. Maintained by U.S. Geological Survey, Little Rock, AR. http://waterdata.usgs.gov/ar/nwis/sw

Zar, J.H., 1996. Biostatistical Analysis (3rd ed.). New Jersey: Prentice Hall.